COMPARISON BETWEEN DIFFERENT ICE MEDIA FOR CHILLING FRESH FISH

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Abstract

Various studies have shown that two-phase slurry ice is more efficient than ordinary flake ice for chilling fresh fish. In most of the studies only one type of slurry ice has been applied, most often prepared in commercial ice-machines. The objective of this work was to investigate both chilling and maintenance of low temperature utilising flake ice and different kinds of ice slurries, both from commercial ice-machines and also manually prepared by mixing crushed ice and brine. The slurry ice particles are smaller when produced in the ice machines than in the latter method and this small size of the ice particles is widely accepted as one of the predominant factors for rapid cooling of fish. Both saithe and a cylinder made of agar were used as specimen in the experiments.

As in other similar studies the cooling rate of all of the different slurry ice types was superior compared to flake ice. Very similar cooling rates were gained using different ice slurries of the same temperature. Therefore, the most important property of the chilling medium was concluded to be temperature since the size of the ice particles seemed to have only minor influence on the cooling rate. The importance of distributing the ice medium evenly when packing fish and ice medium in fish tubs became evident in this work.

In order to maintain low temperature during storage, ice slurries are only better than ordinary flake ice for the first few days of storage. After a few days the faster melting of the ice slurries results in inferior cooling capacity so the flake ice, in general, maintains lower temperature in fish through long storage.

1 Introduction

Numerous papers showing comparison of chilling of fish with flake ice vs. chilling of fish with two-phase ice slurries have been published.

Figure 1 shows the results of an experiment in which a 350 L insulated container was half filled with slurry ice and 30 kg of small to medium sized cod (Davies, 2005). The slurry ice was made of 3 wt. % salt brine with an ice fraction of 35 wt. % and a temperature of -2.6 °C. A second container was packed with cod and flake ice and the temperature evolution in the centre of fish specimen was recorded as in the first container. The performance of the slurry ice is obviously much better. However, the initial temperature of the flake iced fish actually seems to have been higher in the flake iced fish than in the slurry iced fish. More rapid cooling and higher heat transfer rates are explained by larger contact area between the fish and ice particles but also by the fact that the temperature difference between the chilling medium and the fish is larger in the slurry ice case.

Similar studies have been done with plaice (Paul, 1998). The fish was cooled in boxes and the results, presented in Figure 2, show that the time required to chill the plaice below 2 °C was more than three times shorter for the slurry ice than for the flake ice.

Other similar studies (e.g. Egolf el at., 2005) also show a superior cooling rate of slurry ice compared to flake ice for chilling fish.

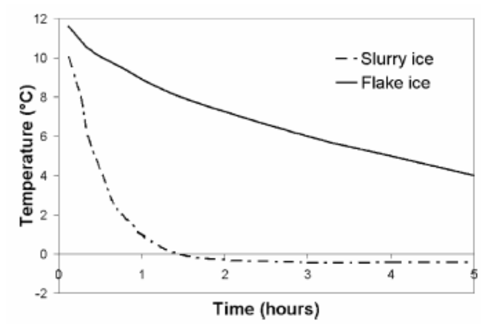

Figure 1. Cooling of cod using flake ice and slurry ice (Davies, 2005).

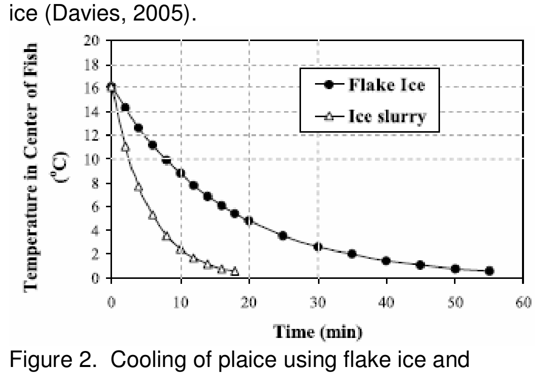

Figure 2. Cooling of plaice using flake ice and slurry ice (Paul, 1998).

Comparison between different slurry ice- and liquid ice types was not found in the literature. Neither has much been published about the cooling capacity of the different ice media. Therefore it was considered useful to include more than one type of slurry ice in the model studies in the present study and not only investigate cooling, but also the maintenance of low temperature during storage.

2 Materials and methods

Model studies were performed at controlled consistent conditions. The different ice media under consideration were the following:

1) *Three types of slurry ice – made with three different types of ice machines.*
   The slurry ice types were made of brine, ranging from 1.5 to 4.0 wt. % in salt concentration, but in most cases from 3.0 to 3.5 wt. %. The ice concentration ranged from 14 to 39 wt. % and the medium initial temperature ranged from -3.0 to -1.1 ℃. The ice particle size was in the interval from 5 - 500 µm according to the ice machine producers.
2) *Flake ice (FI)* with flake size of ca. 1 – 3 cm.
3) *Mixture of flake ice and brine (FI+SW).*
4) *Mixture of crushed flake ice and brine (Crushed FI+SW).* The flake ice was crushed to a particle size of ca. 0.5 – 3 mm.

Ice concentration was determined by measuring the amount of heat required to melt ice, a method widely known as calorimetry. The ice mediums were ranked firstly according to their experimental results on their cooling effect, i.e. how fast the medium cools down a product, and secondly to their ability to maintain cooling during storage.

Cooling of whole saithe of approximate weight 1.5 – 2.0 kg was investigated. The ice to fish ratio was 1:1 in all the slurry ice and liquid ice cases but 4:10 in the flake ice case and the initial temperature of the pollock was approximately 10 ℃.

Another product used was a solid agar cylinder (Figure 3).

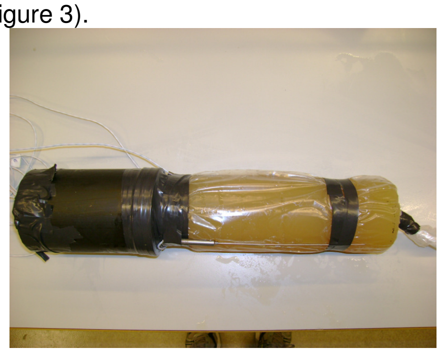

Figure 3. Agar cylinder used in the model studies.

The agar cylinder provides more regular geometrics and better established thermal properties than foodstuffs such as fish, because of the irregular shape of the foodstuffs and variety of heating properties between food components, such as water, fat, proteins etc. The agar cylinder was cast with resistance temperature detectors (RTDs) inside it, which logged the temperature in 3 points from the centre to the surface of the cylinder. Additional three RTDs were used to follow the temperature evolution close to the cylinder. The agar was mixed with salt to lower the freezing point and to avoid the effects of phase changing when cooled with media with temperatures below 0℃. The cylinder's weight was 1.6 kg, its length 30 cm and diameter 8.0 cm and the initial temperature of it was ca. 16 ℃. During chilling it was kept in a styrofoam box immersed in 38 kg of chilling medium.

A fish tub constructed of polyethylene and insulated with polyurethane was used for the whole fish. Its volume is 310 L and was closed with an insulated cover. The Styrofoam box used for the agar cylinder holds approximately 40 L.

In the chilling experiments five layers of whole fish were packed between six layers of cooling medium. In the storage experiments, on the other hand, the fish layers were three and the ice medium layers four. The high number of fish to ice layers was to ensure an even distribution of cooling capacity in the tubs. Each of the three fish layers (top, centre, and bottom) in each tub had four whole fishes with temperature loggers.

Temperature was measured and logged with two types of thermometers:

a. *Resistance Temperature Detectors (RTDs)*
   Platinum 100Pt RTD (resistance temperature detector, see Figure 4) from Omega Engineering, inc., type PR-11 (Omega Engineering Inc. 20.3.2007) were used in the experiments with the agar cylinder. The RTDs are 150 mm long and 1.5 mm in diameter, with three wire configuration.
   The accuracy is ±0.1℃ @ 25℃, resolution is 0.01℃ and operating range is -200 to 850℃. To acquire the rate of heat subtracted by the cooling media the temperature of the agar cylinder was measured in three different locations inside the cylinder, i.e. in the centre, 2 cm above the centre and 2 cm below the centre.

Figure 4. Resistance temperature detector from Omega Engineering.

b. *iButton temperature loggers*
   iButton temperature loggers, type DS1922L (Maxim). This logger has an accuracy of ±0.5 and a resolution of 0.0625 ℃ and an operating range of -40 to 85℃. The diameter is 17 mm and the thickness is 5 mm. The iButton loggers were used in the experiments with the whole fish, positioned as deep in the fish flesh as possible. Three additional temperature loggers were added to the already mentioned loggers in twelve fishes, resulting in a total number of fifteen

loggers for each tub. Two of these three surrounding temperature loggers recorded the temperature in the medium while the last one recorded the ambient air temperature (outside the tub).

2.1 Surrounding temperature

The surrounding temperature for experiments on chilling the agar cylinder was controlled in a cooling chamber (Figure 5).

In the storage experiments with whole fish, a chilled storage in a fish processing plant was used. The ambient temperature for each tub was recorded in the experiments.

Figure 5. Styrofoam box in a cooling chamber used for cooling experiments with the agar cylinder.

2.2 Storage experiments

The purpose of the second part of the experiments was to compare the different mediums in a storage application. Whole fish was packed in tubs for storage with the ice media and stored until the ice melted. The tubs were drained so water from melting ice could exit the tub. As before, the temperature was measured with loggers that were inserted deep in the fish flesh. This experiment lasted for 8 days.

3 Results and discussion

3.1 Chilling of agar cylinder

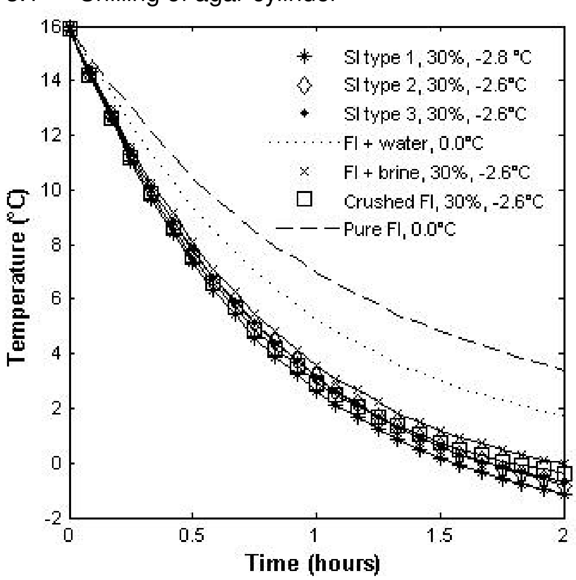

Figure 6. Cooling of agar cylinder using different types of ice media. Temperature is measured in the centre of the cylinder.

From Figure 6 can be stated that unsalted flake ice (temperature 0.0°C with/without water) is the only chilling medium that shows significantly worse chilling performance than the others. The influence of particle size does not seem to be as important as the temperature of the medium.

That can be seen by the relatively small difference between the results for the three slurry ice types compared to the results for the mixture of uncrushed flake ice and brine. The temperature in the centre of the cylinder decreased from 16 °C to approximately -0.8 °C when chilled in slurry ice type 2 and 3 with initial medium temperature -2.6 °C for 2 hours. Chilling the agar cylinder for the same chilling time, using a mixture of uncrushed flake ice and brine, results in a centre temperature of 0.0 °C. The difference between uncrushed flake ice with brine (medium temperature -2.6 °C). vs. uncrushed flake ice with water is apparently larger; where 2 hours of chilling in uncrushed flake ice with water results in a centre temperature of ca. 1.7 °C. The figure also illustrates the effect of medium temperature. Even though slurry ice type 3 is considered to have the largest ice particles of the three slurry ice types, it yields the highest cooling rate since its temperature is 0.2 °C lower than for the two other slurry ice mixtures. Similar results were yielded 2 cm above and below the cylinder centre.

3.2 Chilling of whole fish

Figure 7 shows the results for cooling of whole saithe fish in different chilling media. The pure and uncrushed flake ice notably yields the slowest cooling rate while the results for all the other chilling media are more similar. The average time required to cool whole saithe in pure flake ice from 10 °C to 2 °C is approximately 2 hours and 45 min. The required time to do the same in the other chilling media is approximately one hour, depending on the ice fraction and the medium temperature. Just as for the agar cylinder, the influence of particle size does not seem to be as important as the temperature of the medium. This can be seen by comparing results from two different cases in Figure 7; one with crushed flake ice (approximate particle size 1 mm), the other machine made slurry ice with finer particles. In both of these cases the initial temperature of the medium was -2.7 °C and the ice ratio 39 %.

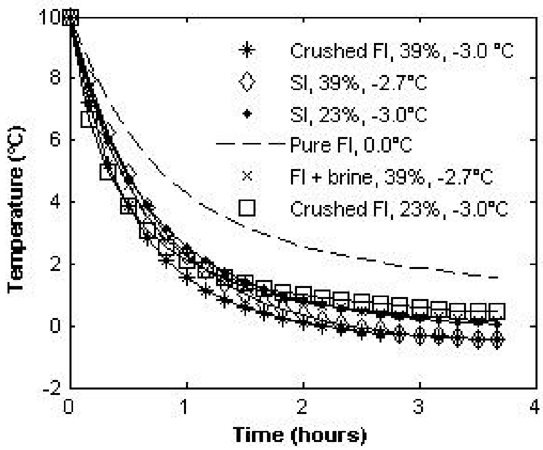

Figure 7. Cooling of saithe using different types of ice media specimen distributed in three layers in each tub.

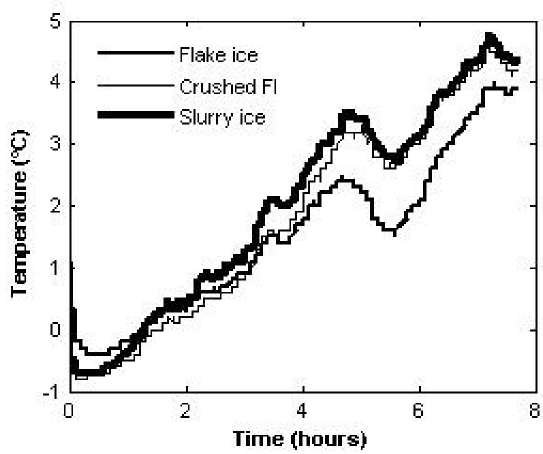

Figure 8. Temperature evolution inside whole saithe stored in different ice media, average temperature for twelve fish specimen in each tub.

3.3 Storage of whole fish

Figure 8 shows the results from the storage experiments with three types of chilling medium. For both slurry ice and crushed flake ice 54 kg of chilling medium was packed evenly in an insulated tub along with 100 kg of saithe. The initial medium temperature was -2.2 °C and the ice ratio 37.1 wt. % which equates to the 20.0 kg of uncrushed flake ice used in the third insulated tub. The three tubs were stored very close to each other in the same chilled storage as can be noted from the similar ambient temperature results not presented here. These experiments show that both crushed flake ice and bubble slurry ice maintain lower temperature in fish during storage for the first 2 – 4 days than the flake ice. This fact is mainly explained by the lower initial temperature of the cooling medium in these two cases. However, because of the small particle size of the two slurry ice media it melts faster than the flake ice resulting in higher temperature for the slurry ice media after the aforementioned 2 – 4 days of storage.

No significant difference of cooling capacity can be noted between crushed flake ice and the machine made slurry ice but as already mentioned, flake ice is the most durable ice medium of the three.

4 Conclusions

As in other similar studies the cooling rate of all of the different slurry ice types was superior compared to flake ice. Very similar cooling rates were gained using different ice slurries of the same temperature. Therefore, the most important property of the chilling medium was concluded to be temperature since the size of the ice particles seemed to have only minor influence on the cooling rate. The importance of distributing the ice medium evenly when packing fish and ice medium in fish tubs became evident in this work.

In order to maintain low temperature during storage, ice slurries are only better than ordinary flake ice for the first few days of storage. After a few days the faster melting of the ice slurries results in inferior cooling capacity so the flake ice, in general, maintains lower temperature in fish through long storage. The number of days it takes to notice better performance of the flake ice depends on factors such as fish/ice-ratio packed in tubs, initial temperature of fish, tub insulation and ambient air temperature.

5 References

Davies, T.W. 2005. *Slurry ice as a heat transfer fluid with a large number of application domains.* International Journal of Refrigeration, 28, p. 108 – 114.

Egolf, P.W., Kauffeld, M., Kawaij, M., 2005. *Handbook on Ice Slurries – Fundamentals and Engineering (p. 259-263)*. International Institute of Refrigeration. Paris, France.

Graham, J., Johnston, W.A., Nicholson, F.J. 1992. *Ice in Fisheries*. FAO Fisheries Technical Paper. No 331. Rome, FAO.

Paul, J. 2002. *Innovative applications of pumpable ice slurry.* Paper given at Institute of Refrigeration, 7 Feb 2002. London, UK.

Maxim. 2007. Product specification. <http://www.maxim-ic.com/quick_view2.cfm/qv_pk/4088> (Accessed 20.3.2007).

Omega Engineering Inc. 2007. Product specification. <http://www.omega.com/ppt/pptsc.asp?ref=fine_diameter_RTD_probes&Nav=temc03> (Accessed 20.3.2007)